THE UNIVERSITY OF ALBERTA

THE EFFECT OF DIRECTION PAUSE AND REST ON A REPLACEMENT ACCURACY TASK

by

© WARREN DUKES

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF PHYSICAL EDUCATION

EDMONTON, ALBERTA

FALL, 1970

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "The Effect of Direction, Pause and Rest on a Replacement Accuracy Task" submitted by Warren Dukes in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

The purpose of this study was to assess the nature of the effects of the following factors on a replacement accuracy task; direction of resetting as related to direction of initial setting, duration of pause in the stop position and duration of rest. There were three levels of direction, two levels of pause and two levels of rest. Both absolute and directional error were measured.

The experimental design was a treatment by subjects, factorial randomized design with repeated measures and replicated four times by each subject. The subjects were nine right handed male graduate physical education students. The collected data was treated by the analysis of variance and Duncan's New Multiple Range Test.

It was concluded that an increase in the duration of pause and rest did not significantly aid recall accuracy. Thus whatever information was gained in the longer durations of pause and rest was not of significant additional use in recall accuracy. Cues obtained during the setting movement did not appear to aid accuracy of recall on a circular replacement accuracy task.

ACKNOWLEDGEMENT

I would like to express my appreciation to Dr. Austin and Dr. Beck for serving on my examining committee and providing guidance for this study. I would like to thank Dr. Wilberg, my chairman for his encouragement and advice.

I would also like to thank my colleagues for serving as subjects and Bob Sharp for his technical assistance.

Special thanks to my wife, Margaret, for her assistance.

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CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

In industry and athletics, as in other facets of life, humans often perform tasks which require a high degree of accuracy. Some of the many factors that affect such accuracy include sensory modality, presence and nature of interpolated tasks, and knowledge of results.

For a variety of reasons, humans are sometimes required to perform under kinesthetic conditions. Under these conditions accuracy has been shown to vary with a number of factors among which are the following: the limb angle (Davies 1966), passive or active movement (Lloyd and Caldwell 1965), the location of the target (Fitts 1947), the direction of movement (Siddall *et al* 1957).

These factors have been isolated and their importance assessed by the application of the inferential method to the "Little Black Box" model, i.e., inferences about the usefulness of a factor are gained from systematically varying levels of a factor (input), and comparing responses (output). In a replacement accuracy task it is assumed that subjects (*S* s) will be able to store information temporarily in a short term memory system. The *S*'s ability to effectively utilize certain aspects of the memory trace of the movement will, it is inferred, be demonstrated in the accuracy of recall movements.

Thus the inferential method, in focusing on performance should disclose elements of the efficiency of the method of receiving, storing, and retrieving the memory trace of movement.

The Problem

It was the purpose of this study to determine the effects of some chosen factors on a replacement accuracy task. The factors chosen were: the direction of resetting as related to the direction of initial setting, duration of pause in the stop position, and duration of rest.

Importance of the Study

Because kinesthesis can provide information concerning limb and joint position, it is a basic component in the control of skilled movement. The method of storing and retrieving such kinesthetic information could impose limitations on physical performance and the learning of motor skills.

Definition of Terms

Replacement Accuracy Task (R.A.T.)

The S turns the handle in a specified direction until given the signal to stop, pauses in this position, then removes his hand and rests as the handle is randomly repositioned. The S then attempts to reset the handle as accurately as he can to the stop position.

Direction

The S sets the handle in either clockwise or anticlockwise

direction. For resetting there is an additional direction of direct recall, i.e., moving the handle across the plate to the estimated stop position.

Set

The initial movement by the S of turning the handle in the appropriate direction to the stop position.

Stop Position

The position in which the S stops turning the handle after being signalled to do so.

Pause

The period spent by the S holding the handle in the stop position.

Rest

The time spent by the S with his hand off the handle after the pause and before the reset.

Reset

The movement by the S of turning the handle in the specified direction to his estimate of the stop position. Recall accuracy refers to the accuracy of such a reset movement.

Kinesthesis (K.)

The discrimination of skeletal movement and position.

Limitations

1. The task in this study required movement in predominantly one dimension. It is assumed that this task will disclose principles

of movement which may be generalized to two and three dimensional tasks.

2. The study is limited by the accuracy of the apparatus and the experimenter reading and recording the scale values. Recordings were made to the nearest degree.

3. S s were chosen from available right-handed male graduate physical education students from the University of Alberta.

CHAPTER II

REVIEW OF LITERATURE

Receptors

Of the many receptors in the muscles, ligaments and joints, those within the joint capsule appear to be most capable of providing information regarding limb position according to Howard and Templeton (1966) and Mountcastle and Powell (1959).

The joint receptors have been identified and their properties explored by many researchers including Skogland (1956), Boyd and Roberts (1953), and Mountcastle and Powell (1959). Some neurons appear especially sensitive to movement in the joints-fast adapting receptors, while the response of others - slow adapting receptors, is dependent on joint angle.

It seems however, that the discharge of joint receptors can be modified under some circumstances:

1. muscular tension: Skogland (1956) found that denervation of the leg muscles in cats reduced the number of sensory nerve endings firing in a particular joint position.

2. cutaneous stimulation: Mountcastle and Powell (1959) found that stimulation distal to the joint suppressed the activity of some cortical neurons related to the joint. Mountcastle and Powell (1959) have shown that afferents from the joint receptors may join cutaneous or muscular nerves.

That one group or receptors is better suited functionally to transmit certain information does not conclusively indicate that

_S_ s can utilize this information. Thus some experimenters have attempted to inactivate some mechanisms in order to determine their contribution to K.

After anaesthetizing the metatarso-phangeal joint, Browne _et al_ (1954), concluded that the sensation of passive movement arose from tension in the joint capsule (and that perception was reasonably insensitive), while sensation of active movement arose from an additional source (muscles and tendons) and was more accurate. However Provins (1958), after anaesthetizing the metacarpo-phalangeal joint, found no evidence that information from active and passive movements were derived from different sources. Provins discussed Browne _et al_ results in terms of Skogland's finding; that in the cat a change in leg muscle tension may modify afferents from the knee joint.

Lloyd and Caldwell (1965) found that the accuracy of positioning of a limb varied with the amount of muscular activity. It was concluded by Lloyd (1968) that a certain minimum of muscular activity facilitates K.mediation of limb positioning. This supports the conclusions of Browne _et al_, and Provins.

Cohen (1957) devised an experiment in which he attempted to assess the contribution of tactile, musculotendinous, and joint mechanisms to position sense in the shoulder joint of humans. On a replacement accuracy task a net mesh, a 1 kgm weight, or both simultaneously were used to 'interfere' with the cutaneous and musculotendinous

mechanisms respectively. He deduced that the principal contribution to accuracy was from the joint mechanism although both the tactile and musculotendinous receptors made significant contributions.

Howard and Templeton (1966) in questioning the validity of this conclusions, point out that Cohen neglected to consider the effect that the weight may have had on joint discharge, and the effect of motor outflow on accuracy (Lashley, 1917).

Replacement Accuracy Tasks and Direction

Posner and Konick (1966) reported that their _S_'s were slightly more accurate in reproducing a movement if the recall movement was in the same direction as the initial movement. The mean absolute errors in millimeters were: same direction (S.D.)-20, opposite direction (O.D.)-22.1. No significance levels were given for this difference. Hughes (1969) mentioned that when _S_'s were given a choice, they reset the handle in the S.D. as they set it. Hughes and Dukes (1969) found in a handle turning study that recall in the S.D. resulted in less absolute mean error than recall in the O.D.

There is scanty evidence concerning the relationship between direction of movement and accuracy, and the above studies offer no discussion of possible reasons why accuracy may be better in one direction than another. It may be that recall in the O.D. is less accurate than that in the S.D., a process that may conveniently be called inhibition. It may be that recall in the S.D. is better than that in the O.D., a process that may be called facilitation.

After a brief review of theories of retention, studies relating to the above question of facilitation or inhibition will be reviewed.

Decay Theory of Retention

Brown (1958) has suggested that a memory trace becomes consolidated and resistant to decay if the S is allowed to rehearse after presentation of the 'message'. Interpolated material causes forgetting by interrupting the consolidation process. S s performing simple R.A.T. under K. conditions have however demonstrated varying degrees of decay when the intervals have been unfilled.

Adams and Dijkstra (1966) using a linear motor task, found that the mean absolute error was much greater after an interval of 120 seconds compared with that after 10 seconds.

Ascoli and Schmidt (1969) in a similar experiment confirmed the above results for absolute error and found that directional error was little changed by the delay; S s undershot the target by roughly the same amount.

Posner (1967) reported that forgetting occurred over an interval of 20 seconds, but his S s turned 180° in that time, and this movement was not present in the immediate recall.

Hughes (1969) found that immediate recall accuracy did not differ from recall accuracy after a 10 second interval; a result similar to that in Schmidt and Stelmach's (1968) study in which intervals of 12, 22

and 37 seconds were used.

Pepper and Herman (1970) have suggested that rehearsal of a motor item would require an overt act which is prohibited by instructions. Thus an unfilled interval may not provide an opportunity for rehearsal of a motor task as it may for a verbal task.

Interference Theory of Retention

It is assumed that forgetting is dependent upon competition from other materials learned prior to (proactive inhibition) or subsequent to (retroactive inhibition R.I.) the items to be remembered.

Retroactive Inhibition (R.I.)

Wickelgren (1966) found increases in R.I. as a result of varying the phonemic similarity of the interpolated material to the material to be recalled. He concluded that R.I. may work in two ways, either by the prevention of rehearsal, or by the interpolated material being similar to the stored material. However in a card sorting task, Taylor *et al* (1966) found that neither the difficulty nor the similarity of the interpolated task (I.T.) was related to the error.

Conrad (1960) found that the I.T. of prefixing a 7 digit number by "0" affected recall accuracy detrimentally, and did so regardless of the temporal location of the "0".

Boswell and Bilodeau (1964) reported that zeroing a lever did not affect the accuracy of lever positioning, whereas picking a pencil off the floor did. This study has been criticized by both Bahrick (1966) and Underwood (1966) because of the use of a correlation measure as the index of forgetting, and also by Pepper and Herman (1970) who claim that the mean error data (which was not reported in the 1964 paper) did not in fact indicate a differential change in retention for the two conditions. Schmidt and Stelmach (1968) found that a similar motor I.T. disrupted S s' postural set rather than providing interference.

Blick and Bilodeau (1963) found in an arc drawing task that interpolation of movements quantitatively similar to the criterion task did not produce error. The inclusion of an I.T. of the same length but in the opposite direction to the criterion did not produce diminished accuracy after 8 trials with knowledge or results. All trials were started in different locations so that S would not learn to dial to a location but be forced to dial a certain distance.

Stelmach and Barber (1970) gave S s knowledge of results on a lever positioning task and found that an antagonistic I.T. did not cause forgetting.

Williams et al (1969) reported an increase in absolute error in recall relative to a resting condition when S s were required to perform a series of rapid levering tasks during the retention interval.

Three theories involving combinations of the decay and interference concepts have recently been proposed by the following experimenters: Wickelgren (1966), Posner (1966) and Pepper and Herman (1970).

Facilitation

If it is assumed that S s are more accurate in recalling in the S.D., then this could be due to the utilization of movement cues obtained prior to the stop position. If this were so then an increase in repetitions of the set movement could be expected to result in increased accuracy, as the movement cues would be 'heightened' or more familiar to the S s (Increased accuracy with repetition could also be due to other factors e.g. time. If the S learns a given distance to be reproduced and consistently moves at a steady rate he could, with knowledge of results, increase accuracy by attending to the duration of the movement. This alternative will be discussed later).

Adams and Dijkstra (1966) found no difference in accuracy when the number of repetitions of the movement to be recalled, were 1, 3 and 6. However accuracy was markedly increased when the number of repetitions was increased to 15.

Posner (1967) has provided what could be viewed as a test of whether S s use cues from movements prior to the stop position or whether they use duration. His S s dialed a fixed distance that was to

be reproduced under two conditions. In one recall condition the handle was in the same location as it had been for the initial set condition. In a second recall condition the handle was set in a different location. Posner found that S s were more accurate when the handle was in the same location for the set and the reset trials. This result supports the initial assumption made in this section i.e. facilitation, and casts doubt on alternatives.

It has been found, e.g. Ellis et al (1968), that with longer movements there is increased accuracy in timing. Ellis et al suggested that the increased proprioceptive feedback produced increased accuracy and control.

Mountcastle and Powell (1959) have stated that a given movement will evoke a spatial - temporal neural cortical profile, and Mountcastle (Davies 1966) has speculated that the direction of movement by which a limb reaches a given position may have some bearing on the sensitivity of subsequent movement. Thus replication of a movement in the same direction as an earlier movement may aid accuracy of recall of the stop position.

Inhibition

There is less direct evidence available with which to evalute the assumption that recall in the O.D. could be inhibiting.

Mackworth (1962), in a study of immediate memory span of digits, found recall was less accurate with visual selection (manual response)

than with dictation and concluded "it appears that the overt act of recall produces forgetting, and that the amount of forgetting depends upon the nature of the response".

However this by itself does not hint at reasons why recall in the O.D. should impair accuracy more than in the S.D.

The results of studies concerned with interference through R.I. have already been presented. To summarize, it appears that despite the similarities between the set and the O.D. recall movement, R.I. interference does not readily occur with a single movement (Blick and Bilodeau, 1963), but may with a series of movements (Williams et al. 1969). As well, Sanders (1961) and Pylyshyn (1965) have reported the longer the interval before the I.T. the better the recall; a finding which does not support the inhibitory explanation.

Finally it could be that the initial movement is coded in such a way that recall in the O.D. is less efficient than that in the S.D. It was suggested regarding facilitation that replication of a movement evoking a similar profile may aid accuracy; conversely a different movement (O.D.) may hinder accuracy.

CHAPTER III

METHODS AND PROCEDURES

Sample

The S s were nine male students of the University of Alberta chosen from those available at the time of testing. They were right handed and free from any obvious disabilities that could limit their performance on the task.

Task

The S s who were standing, were required to rotate a handle that was mounted in the vertical plane in front of them (see figure 1). The experimenter (E) placed the S's right hand on the handle and applied gentle pressure to indicate the direction in which to rotate the handle as specified for that trial. The S stopped turning the handle on the sound of a buzzer and held his hand in that stop position until a "click" occurred, indicating that he remove his hand from the handle and place it by his side.

After the appropriate time lapse the E replaced the S's hand on the handle and hand pressure was again used to indicate the direction of resetting.

Independent Variables (I.V.)

Three factors were chosen as I.V.:

<u>Direction</u> The three direction conditions of resetting were:

same direction (S.D.)

opposite direction (O.D.) and

direct recall.

The three direction conditions were chosen in an attempt to find reasons, assuming the results of the Hughes and Dukes (1969) study were replicated, for the S.D. recall condition being more accurate than the O.D. recall condition. If the S.D. condition results in more accuracy than the O.D. condition, then the implications of the location of the direct recall mean error (facilitatory or inhibitory) will be deduced.

<u>Pause</u> The two levels of pause in the stop position were:

pause for a duration of 3 seconds and

pause for a duration of 11 seconds.

Hughes and Dukes (1969) used levels of pause of 1 and 11 seconds. As in the present study it was not possible to arrange the direct recall condition in less than 3 seconds, this duration was used. The levels of pause were chosen then to enable comparisons to be made between the results of the present study and those of the Hughes and Dukes (1969) study.

<u>Rest</u> The two levels of rest were:

rest for 3 seconds and

rest for 11 seconds.

The levels of rest were chosen to enable comparisons to be made

between the effects of pause and the effects of rest on the accuracy of recall of the stop position.

Dependent Variable

The dependent variable was the numerical difference in degrees between the stop position and the S's estimate of that position. Measurements were recorded to the nearest degree from the scale marked on the metal plate. Both absolute and directional error were recorded.

The S's estimate of the stop position could be on either side of the actual stop position. The initial direction was used as the reference to determine directional error. If the S's estimate of the stop position was on the side of the stop position from which the initial movement was made then this was designated "undershooting" and was assigned a negative value.

If the S's estimate of the stop position was on the opposite side of the stop position from which the initial movement was made, then this was designated as "overshooting" and was assigned a positive value. The above rules were used to determine the directional error for all the recall conditions.

Experimental Design

The I.V. were combined in a factorial manner to give 12 (3x2x2) experimental conditions. Each of these conditions was given with both the clockwise and anticlockwise setting directions. The experiment involved a treatment by S s factorial model with four replications.

Statistical Analysis

Both absolute and directional error were subjected to the following statistical analyses. Mean error scores were calculated for each of the experimental conditions and for the main effects. A three way analysis of variance (fixed model) was computed in order to ascertain the effect of the three independent variables. A four way analysis of variance (fixed model) incorporating the setting direction in addition to the three independent variables was also computed. Further a six way analysis of variance (mixed model) in which S s and replications were also treated as main effects was computed. A test on means using Duncan's New Multiple Range Test followed.

The $\alpha = .01$ level of rejection was used for all tests. The figures for the $\alpha = .05$ level given in some instances in this study are only for the reader's benefit.

Apparatus

The apparatus consisted of an axle mounted in bearings, which were firmly attached to a Dexion frame (see figures 1 and 2). The centre of the axle was 45 inches from the floor. An 8 inch metal arm was fixed to one end of the axle. This arm had a hole and sleeve parallel to and 6 3/4 inches from the axle. Through this hole a detachable 4 1/2 inch long pin was passed. Placed over the pin was a freely rotating handle 3 1/2 inches long and 1 inch wide.

A plexiglass plate, approximately 4-1/2 inches long and 3-1/4 inches wide, was attached to the handle and also linked by a fine chain to the axle via a freely rotating washer.

Surrounding the axle and 1/8 inch from the handle was an aluminum plate, 12 inches in diameter, which was marked off in degrees at its circumference. The handle at one end of the metal arm could be rotated while the pin was attached. If the pin was detached the handle could be moved independently of the arm. In this latter situation the handle which would be linked only by the chain to the axle could be moved across the aluminum plate. The arm containing the handle, was cut away so that the location of the centre of the arm (and the handle) could be read from the degrees on the plate. The plexiglass was also marked so that the location of the handle, when free from the pin and arm, could also be read in degrees.

Two Hunter Decade Timers, Model III B were used to indicate the time intervals and the buzzer on a GraLab Universal Timer was used to indicate the stop position.

The S's wore opaque goggles throughout all trials.

Testing Procedure

1. The S's right hand was placed on the randomly positioned handle and the setting direction indicated to the S by slight hand pressure.

2. The S commenced turning in his own time and stopped after the buzzer had sounded when the handle coincided with a predetermined random position. The exact location of the handle was recorded by the E.

3. 3 or 11 seconds after the "buzz" a "click" was given to indicate to the S to remove his hand from the handle and place it by his side.

4. The handle was randomly relocated and 3 or 11 seconds after the "click" the S's hand was again placed on the handle and the direction of resetting indicated.

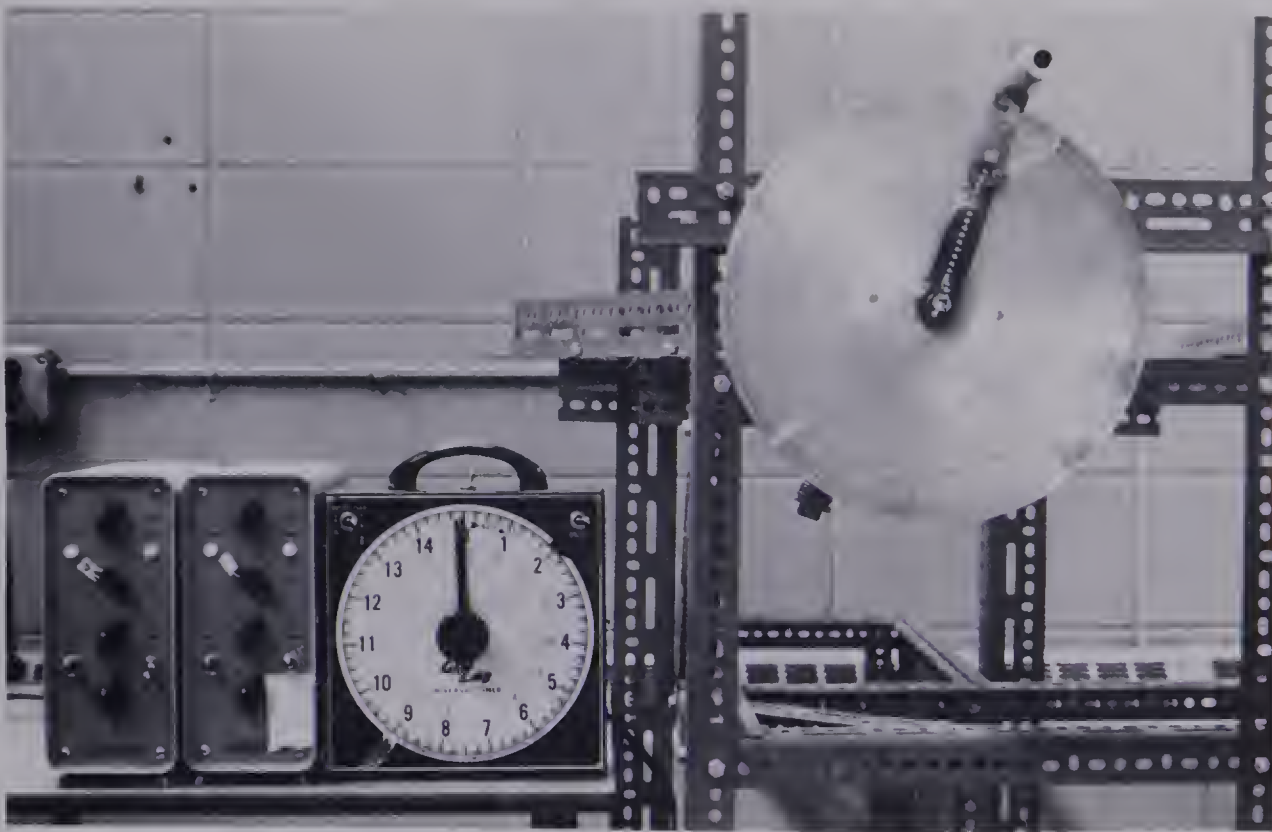
5. The S turned the handle in his own time to his estimate of the stop position. The location of the handle was recorded.

Random location of the handle was determined by a set of random numbers. For location for the reset a sector of 25^{o} on either side of the stop position was excluded, as the influence of prior movement on accuracy was being studied. A 30^{o} sector 180^{o} opposite the stop position was also excluded because during free recall the S could hit the axle with the plexiglass.

S's were given one training and two testing sessions with no two sessions occurring on the same day. During the training session the S's were familiarized with the equipment and the responses required following the auditory signals. A series of trials with the various conditions equally represented was given. For the direct recall condition the S's were instructed to approach their estimate of the

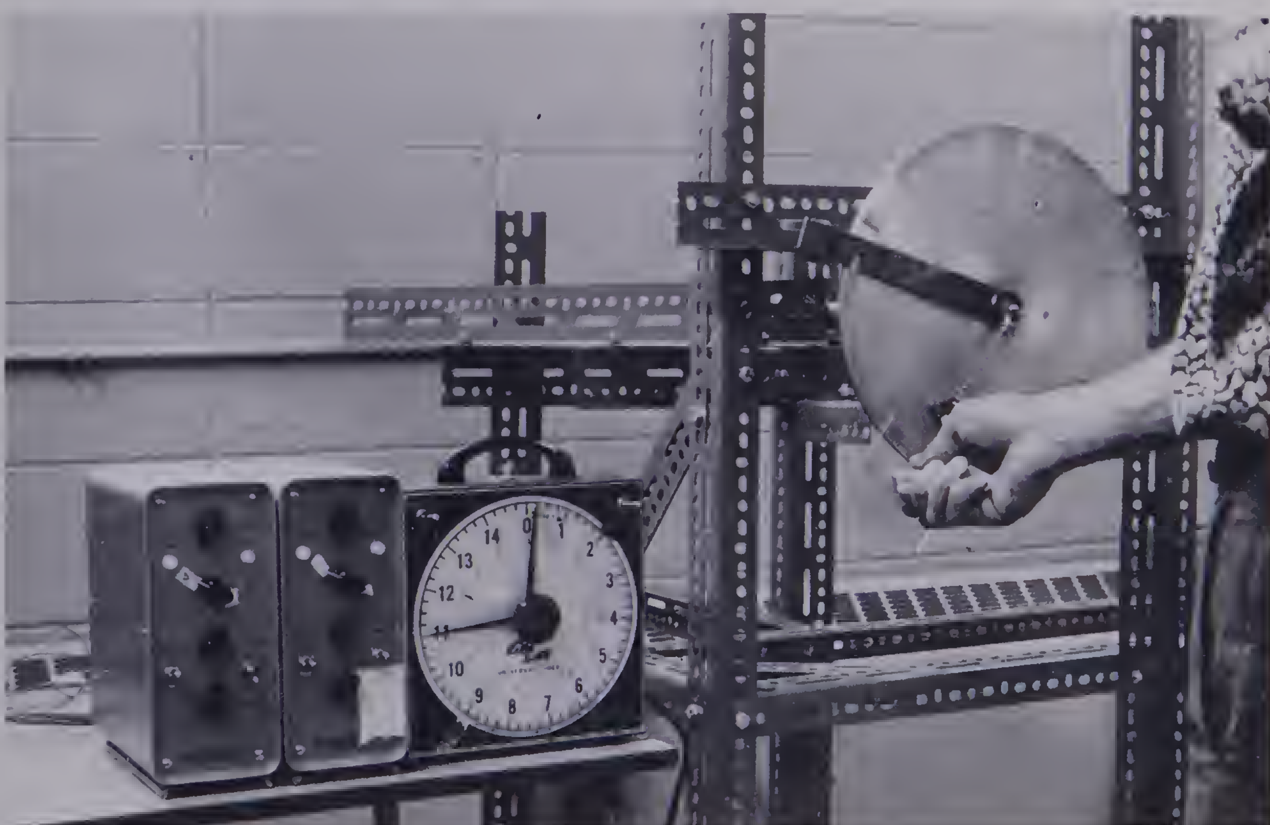
stop position by moving the handle directly across the plate, rather than along its circumference. All S's had a rest halfway through the testing sessions. During the training session and before each testing sessions the S's were reminded to be as accurate as possible in recalling the stop position.

FIGURE I



View of Apparatus with Pin
Attached to Arm and Handle

FIGURE 2



View of Apparatus with Pin
Detached for the Direct
Recall Condition

CHAPTER IV

ANALYSIS

Hypothesis

From a review of literature the following three hypotheses were formed with both absolute and directional error as the criteria:

H_1: Pause 3 seconds = Pause 11 seconds

H_2: Rest 3 seconds = Rest 11 seconds

H_3: Same Direction = Opposite Direction = Direct Recall

If S.D. < O.D. then the implications of the location of the direct recall mean error (facilitatory or inhibitory) were to be deduced.

The first hypothesis was stated in the null form as a review of the literature did not reveal any relevant studies other than the pilot study by Hughes and Dukes (1969).

The second hypothesis was also stated in the null form as Schmidt and Stelmach (1968), Wilberg (1969) and Hughes (1969) had, among others, reported no decay in accuracy in a comparable task over comparable time periods.

The third hypothesis was stated in the null form as the studies by Posner and Konick (1966) and Hughes and Dukes (1969) were felt to be too inconclusive on which to base a hypothesis other than the null. Also there did not appear to be any prior publications concerned with what is termed in this study 'direct recall'.

Results

The results of both absolute and directional error were placed on IBM data cards. A Fortran IV multi-way analysis of variance was used on an IBM 360/67 computer.

The means of the twelve experimental conditions for both absolute and directional error are given in Table I. Each mean was based on 72 readings; there were 864 readings in the entire experiment. The mean errors for each level of the main effects are given in Table II. The errors for initial starting direction are also given. As this experiment involved replications, assumptions underlying the analysis of variance may have been violated. Geisser and Greenhouse (Edwards, 1968) have shown the effect on the degrees of freedom if this violation is maximal and their conservative test diminishes the degrees of freedom by the maximal amount. In the present study it was assumed that the violation was maximal and the conservative degrees of freedom were used where applicable.

In Table V and VI the results of the tests on the means for all three levels of the direction main effect can be seen.

For absolute error there was a significant difference between the mean of direct recall and that of S.D. (at the .01 level), and between the mean of direct recall and that of O.D. (at the .01 level).

For directional error the difference between the means of S.D. and O.D. was significant at the .01 level.

Excerpts from the four way analysis of variance showing the F. ratio for the initial starting direction reveal no significant difference at the 0.1 level for either absolute or directional error (Tables VII and IX).

Excerpts from the six way analysis of variance for absolute error are given in Table VIII. These excerpts show the F. ratios for S's, Replications, and those interactions that are significant at the α = .01 level. Exceprts from the six way analysis of variance for directional error are given in Table X. These excerpts show the F. ratios for S's, Replications and the S x Replication interaction. Replications were not significant at the .01 level for either absolute or directional error. The appropriate error term for both of the above factors was the S x Replication interaction.

The S x Direction interaction on absolute error was not significant at the .01 level. The error term used to evaluate the above interaction was the S x Direction x Replication interaction.

The F. ratio for the S x Pause x Initial Starting Direction for absolute error was also given, as it was significant at the .01 level.

Discussion

Pause

The effect of holding the handle in the stop position for 3 or 11 seconds was not significant at the .01 level for either absolute or directional error. Consequently the first hypothesis, which was stated in the null form, was not rejected.

TABLE I

MEAN ERROR FOR THE TWELVE
EXPERIMENTAL CONDITIONS

Condition	Recall Direction	Pause	Rest	A.E.	D.E.
1	S.D.	3 sec.	3 sec.	8.14	+ 1.47
2	S.D.	11 sec.	3 sec.	8.00	+ 3.94
3	S.D.	3 sec.	11 sec.	7.86	+ 3.33
4	S.D.	11 sec.	11 sec.	6.82	+ 1.35
5	O.D.	3 sec.	3 sec.	8.25	- .25
6	O.D.	11 sec.	3 sec.	9.03	+ .89
7	O.D.	3 sec.	11 sec.	7.76	- 1.01
8	O.D.	11 sec.	11 sec.	9.64	- .61
9	D.R.	3 sec.	3 sec.	8.85	+ .82
10	D.R.	11 sec.	3 sec.	9.42	+ .53
11	D.R.	3 sec.	11 sec.	10.28	+ .76
12	D.R.	11 sec.	11 sec.	10.96	+ 1.29

LEGEND

S.D. - Same Direction

O.D. - Opposite Direction

D.R. - Direct Recall

A.E. - Absolute Error

D.E. - Directional Error

TABLE II

MEAN ERROR FOR EACH LEVEL
OF MAIN EFFECTS

Main Effect	Level	Error: Absolute	Error: Directional
Recall Direction	Same Direction	7.71	+ 2.52
	Opposite Direction	8.67	- .25
	Direct Recall	9.88	+ .59
Pause	3 sec.	8.52	+ .85
	11 sec.	8.98	+ 1.06
Rest	3 sec.	8.61	+ 1.06
	11 sec.	8.89	+ .85
Starting Direction	Clockwise	8.29	+ .99
	Counterclockwise	9.21	+ .92

TABLE III

SUMMARY OF THREE WAY ANALYSIS OF VARIANCE - ABSOLUTE ERROR

Source	df	Conservative df	Mean Square	F
Direction (D.)	2	1	340.4617	7.0137 **
Pause (P.)	1	1	44.4630	.9160
D.x P.	2	1	67.7095	1.3949
Rest (R.)	1	1	16.1157	.3320
D. x R.	2	1	90.7303	1.8690
P. x R.	1	1	.5602	.0115
D. x P. x R.	2	1	18.0011	.3708
Error	852	284	48.5426	

CRITICAL F. VALUES

df	.05	.01
1, 284	3.86	6.70

** Significant at α = .01 level.

TABLE IV

SUMMARY OF THREE WAY ANALYSIS
OF VARIANCE - DIRECTIONAL ERROR

Source	df	Conservative df	Mean Square	F
Direction (D.)	2	1	599.3887	4.8280
Pause (P.)	1	1	6.1678	.0497
D. x P.	2	1	26.2824	.2117
Rest (R.)	1	1	6.5104	.0524
D. x R.	2	1	75.8750	.6112
P. x R.	1	1	69.4734	.5596
D. x P. x R.	2	1	193.8934	1.5618
Error	852	284	124.1493	

CRITICAL F. VALUES

df	.05	.01
1,284	3.86	6.70

TABLE V

DUNCAN's NEW MULTIPLE RANGE TEST APPLIED TO THE DIFFERENCE BETWEEN MEANS FOR THE THREE LEVELS OF RECALL DIRECTION - ABSOLUTE ERROR

MEANS	7.7048	8.6702	9.8750
	Same	Opposite	Direct Recall
7.7048	-	.9654	2.1702 **
8.6702		-	1.2048 **
9.8750			

Shortest Significant Range

	.05	.01
R_2	= 1.1379	1.1978
R_3	= 1.4954	1.5582

** Significant at the α = .01 level.

TABLE VI

DUNCAN'S NEW MULTIPLE RANGE TEST
APPLIED TO THE DIFFERENCE BETWEEN
RECALL DIRECTION - DIRECTIONAL ERROR

MEANS	- .2465	+ .5867	+ 2.5242
	Opposite	Direct Recall	Same
- .2465	-	.8332	2.7707 **
+ .5867		-	1.9375
+2.5242			-

Shortest Significant Range

	.05	.01
R_2	= 1.8325	2.4083
R_3	= 1.9290	2.5095

** Significant at the α = .01 level

TABLE VII

EXCERPTS FROM FOUR WAY ANALYSIS OF VARIANCE - ABSOLUTE ERROR - SHOWING F RATIO FOR INITIAL DIRECTION

Source	df	Conservative df	Mean Square	F
Initial Direction	1	1	179.6713	3.7431
Error	840	280	48.0008	

CRITICAL F VALUES

df	.05	.01
1,280	3.86	6.70

TABLE VIII

EXCERPTS FROM SIX WAY ANALYSIS OF VARIANCE - ABSOLUTE ERROR - SHOWING THE F RATIOS FOR S. REPLICATIONS AND SIGNIFICANT INTERACTIONS

Source	df	Cons. df	Mean Square	F
Subjects (S.)	8	8	204.4557	2.7306
Replications (Rep.)	3	3	65.3488	.8727
Error: S. x Rep.	24	24	74.8737	
S. x Direction (D.)	16	8	84.6439	2.6788
Error: S. x D. x Rep.	48	24	31.5975	
S. x P. x I.D.	8	8	162.3856	5.7707 **
Error: S. x P. x I.D. x Rep.	24	24	28.1386	

CRITICAL F RATIOS

df	.05	.01
3.24	3.01	4.72
8.24	2.36	3.36

LEGEND

Cons. df - Conservative df

P. - Pause

I.D. - Initial Direction

** Significant at the α = .01 level.

TABLE IX

EXCERPTS FROM FOUR WAY ANALYSIS
OF VARIANCE - DIRECTIONAL ERROR - SHOWING
F RATIO FOR INITIAL DIRECTION

Source	df	Conservative df	Mean Square	F
Initial Direction	1	1	2.3438	.0187
Error	840	280	125.1644	

CRITICAL F VALUES

df	.05	.01
1,280	3.86	6.70

TABLE X

EXCERPTS FROM SIX WAY ANALYSIS
OF VARIANCE - DIRECTIONAL ERROR - SHOWING
F RATIOS FOR SUBJECTS AND REPLICATIONS

Source	df	Conservative df	Mean Square	F
Subjects (S.)	8	8	574.2495	4.3161 **
Replications (Rep.)	3	3	127.6153	.9591
Error: S. x Rep.	24	24	133.0458	
S. x Direction (D.)	16	8	296.0032	1.7338
Error: S. x D. x Rep.	48	24	170.7214	

CRITICAL F VALUES

df	.05	.01
3.24	3.01	4.72
8.24	2.36	3.36

** Significant at the α = .01 level.

The only other study located by the author, in which this variable was investigated was the pilot study by Huges and Dukes (1969). In that study the effect of pause for 1 or 11 seconds was significant at the .05 level using the Geisser and Greenhouse conservative test. For a pause of 1 second the absolute mean error was 11.2° and for a pause of 11 seconds it was 9.9°. In the present study the respective means for absolute error for pauses of 3 and 11 seconds were 8.5° and 9.0°. Reasons for the discrepancy between the two studies are not clear, but could be related to the use of a 3 second pause in the present study compared with a 1 second pause in the prior study.

In the Hughes and Dukes (1969) study the S's used were mainly first year university students compared with the graduate physical education students used in the present study. If a difference in accuracy exists with any organismic variable, for example age or motor ability, then the difference between the studies may be explicable in these terms. Assuming such a difference in accuracy does exist, then the S x Pause interaction would probably be significant whereas in fact in neither of the studies was the S x Pause interaction significant at the .01 level for either absolute or directional error.

However the S x Pause x Initial Starting Direction was significant at the .01 level for absolute error though not for directional error. But the meaning of this interaction and its usefulness in explaining the discrepancy between the studies is unclear.

Adams and Dijkstra's (1966) S's increased their accuracy in the movement of a set distance when the number of reinforcements was 15 compared with their accuracy when the number of reinforcements was 1 and 3; whereas in the present study it appears that holding the limb in the position to be recalled for 11 seconds does not aid accuracy.

Rest

It can be seen in Tables III and IV that the main effect of rest was not significant at the .01 level. Therefore the second hypothesis which was stated in the null form was not rejected.

This finding was similar to the results of studies by Hughes (1969) Wilberg (1969) and Carre (1969) in which the accuracy of immediate recall of K. material did not differ from that after an unfilled interval of 10 seconds. The finding in the present study was in disagreement with the results of studies by Ascoli and Schmidt (1969) and Adams and Dijkstra (1966). In these two studies however, longer intervals of 120 seconds were used.

The results of three studies which used intervals between the range of 10 and 120 seconds yield conflicting results. Schmidt and Stelmach (1968) found no loss in the accuracy of retention of K. information over delays of 12, 22, and 37 seconds; a result similar to that found by Posner and Konick (1966) using a 30 second delay. However Posner (1967) found significant forgetting over a 20 second period that was filled only with a 180° turn by the S's. It is possible that Schmidt and Stelmach's (1969) finding that postural set is very important in lever positioning tasks could explain the

forgetting found by Posner (1967) over such a short time interval.

Direction

From the three way analysis of variance, direction was found to be significant at the .01 level for absolute error. For absolute error there was a significant difference between the means of the direct recall condition and S.D. (.01), and between the means of direct recall and O.D. (.01). The difference between the means of S.D. and O.D. for absolute error was not significant at the .01 level. The absolute error for the direct recall condition was significantly larger than the error for the other recall conditions. The third hypothesis regarding absolute error was rejected.

For directional error the difference between the means of S.D. and O.D. was significant at the $\alpha = .01$ level. The directional error for the S.D. condition contained more overshooting than the error for the O.D. condition. The third hypothesis regarding directional error was rejected as the $\alpha = .01$ level was obtained. (The directional error mean for the S.D. condition differed from the mean for the direct recall condition at the $\alpha = .05$ level, an unacceptable level for this study).

The implications regarding inhibition or facilitation cannot however be drawn as the requirement of the S.D. < O.D. was not met. This requirement was formed as a result of the Hughes and Dukes (1969) study in which it was found that the absolute error for the S.D. was significantly less than the error for O.D. (The mean for S.D. was 9.1^{o} error and that for O.D. was 12.0^{o} error) The direct recall condition was introduced in the present study in an attempt to find reasons, assuming

the results of the earlier study were replicated, for the S.D. being more accurate than the O.D. recall condition. It was reasoned that if for example:

$$S.D. < O.D. = \text{direct recall}$$

then a case could be made for the S's utilizing prior movement cues in a facilitatory fashion.

As it was not found in this study that the error for the S.D. was not significantly less than that for the O.D., reasons need to be advanced in an attempt to explain the discrepancy between the two studies. It is possible that in the Hughes and Dukes study a Type I error was made, that is the null hypothesis regarding the relationship between the mean error for the S.D. and that for the O.D. may have been true but was falsely rejected. And it is possible that a Type II error was made in the present study, that is the relevant null hypothesis may have been false but it was not rejected.

As the S's used in the present study were graduate physical education students compared with the use of mainly first year university students in the Hughes and Dukes study then this could be a contributing factor. The absolute mean error for the studies are given below.

	Hughes and Dukes	Hughes's thesis	Present study
Same Direction	9.14°	9.05°	7.71°
Opposite Direction	12.00°		8.67°

(Hughes's (1969) study was not concerned with direction but as he noted that in all of the 648 trials except one the S's recalled in

the S.D. then the results can be included in the above table. Hughes's S s were also first year university students).

If a difference in accuracy exists with, for example motor ability then a S x Direction interaction could be expected. This was found to be the case in the present study for absolute error at an unacceptable level (.05). It was thought that if the S s used in the present study were relatively more accurate on the O.D. recall than those S s used in the Hughes and Dukes (1969) study then this may assist in explaining the interaction and point to a reason why the S.D. accuracy was not less than the accuracy for the O.D. condition. The S s used in the present study were arbitrarily divided into two groups based on their accuracy on the S.D. recall condition.

TABLE XI

PERCENT INCREASE IN ERROR
FROM S.D. MEAN TO O.D. MEAN
FOR TWO ACCURACY GROUPS

Accuracy based on S.D.	S.D. Mean	O.D. Mean	% increase in error
Five most accurate S s	6.64	7.33	10.39%
Four least accurate S s	9.04	10.29	13.80%

The more accurate S s on the S.D. were relatively more accurate on the O.D. than the less accurate S s. However the difference in

percentage increase in error between the two groups appears to be too small to account entirely either for the interaction or for the difference between the two studies under the conditions of S.D. and O.D.

In the present study the results for absolute error can be abbreviated:

$$\text{S.D.} = \text{O.D.} < \text{direct recall.}$$

It appears that when Ss move the handle on a fixed path that they are more accurate in a circular R.A.T. than when they move directly across to recall the stop position. Recalling in the O.D. is similar to direct recall in that generally the only position that the recall movement has in common with the setting movement is the actual stop position. Prior movement cues would be present for the S.D. recall condition but not for the O.D. recall condition. As the mean error for the S.D. and O.D. recall conditions did not differ significantly for absolute error it appears that prior movement cues did not aid replacement accuracy.

In recalling in the S.D. and O.D. the S had to move the handle along one path and only needed to decide where to stop. Recalling under the direct recall condition differed in that the S (being instructed to go directly to the stop position) had to recall the location of the stop position from the moment his hand was placed on the handle at the start of the reset movement. This difference could be one reason for the results obtained in this study.

Using Duncan's New Multiple Range Test it was found that there was a significant difference, at the $\alpha = .01$ level between the mean

error for the S.D. condition, overshooting, and that for the O.D. condition, undershooting. Adams and Dijkstra (1966), Brown et al (1948), and Schmidt and Stelmach (1969) all found undershooting of a target location. The present study is not directly comparable to the above mentioned studies in that they did not investigate the effects of various recall directions on accuracy. Thus they could not compare the relationship between S.D. and O.D. mean error as regards to directional error.

Initial Direction

Initial direction was not a factor of primary interest in this study and no hypothesis concerning it was formed. It was used in this study as a control variable to balance out any possible effects that it may have caused. In the analysis of the results, it was treated as a main effect to test and see if it did have any significant effect on accuracy. Excerpts from the four way analysis of variance showing the F. ratio for the initial starting direction reveal no significant difference at the $\alpha = .01$ level for either absolute or directional error (Tables VII and IX).

Subjects and Replications

There was considerable individual variation between the S s on both absolute and directional error, the latter being significant at the .01 level. The S x Replication interactions were not significant

at the .01 level for either absolute or directional error (F. ratios of 1.6596 and .9542 respectively were obtained). As replications were not significant at the .01 level then S s, whatever their level of accuracy, did not differ markedly from it over replications.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

The purpose of this study was to assess the nature of the effects of the following factors on a replacement accuracy task; direction of resetting as related to direction of initial setting, duration of pause in the stop position and duration of rest. There were three levels of recall, two levels of pause and two levels of rest. The experimental design was a treatment by subjects factorial randomized design with repeated measures and replicated four times by each subject. The subjects were nine right handed male graduate physical education students.

Following a review of the literature three null hypotheses were formed for both absolute and direction of error.

1. There was no significant difference in replacement accuracy between the 3 second pause condition and the 11 second pause condition.

2. There was no significant difference in replacement accuracy between the 3 second rest condition and the 11 second rest condition.

3. There was no significant difference in replacement accuracy between the recall condition of same direction, opposite direction and direct recall.

The collected data was treated by analyses of variance and Duncan's New Multiple Range Test.

Conclusions

Within the limitations of the study the following conclusions were made.

An increase in the duration of pause and rest did not significantly aid recall accuracy. Thus whatever information was gained in the longer durations of pause and rest was not of significant additional use in recall accuracy.

The use of prior movement cues was assessed by comparing the recall accuracy of S.D. and O.D. recall conditions. The only significant difference between these recall conditions was with directional error. The S.D. condition resulted in more overshooting than the O.D. condition. It is concluded that prior movement cues did not significantly aid recall accuracy on a circular replacement accuracy task.

Further Direction

A study utilizing a more powerful experimental design, subjects of different abilities and sophisticated apparatus, e.g. an XY recorder may better assess the relationship between direction and accuracy as outlined in this study.

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APPENDIX

TESTS FOR RIGHT HANDEDNESS

TESTS FOR RIGHT HANDEDNESS

Only those volunteers who showed righthandedness on the following tests were chosen as _S_'s

1. signing their names.
2. turning over some coins lying on a table.